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(54) **METHODS AND APPARATUSES FOR NETWORK FLOW ANALYSIS AND CONTROL**

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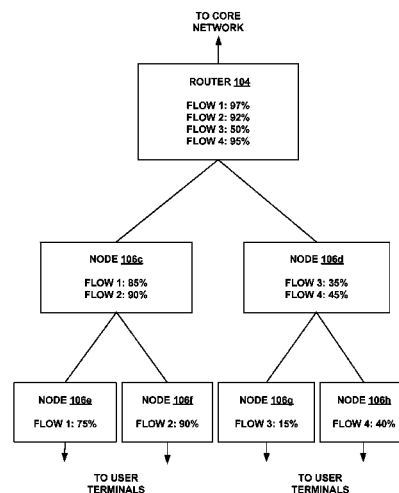
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**ABSTRACT**

Techniques for network packet flow analysis and control are described herein. One example method may include obtaining network topology information corresponding to a plurality of nodes of an access network, receiving communication monitoring messages from two or more of the plurality of nodes, wherein the communication monitoring messages include communication information corresponding to a plurality of communication layers, and determining information loss statistics associated with the plurality of nodes based on the communication monitoring messages and the network topology information.

**20 Claims, 7 Drawing Sheets**



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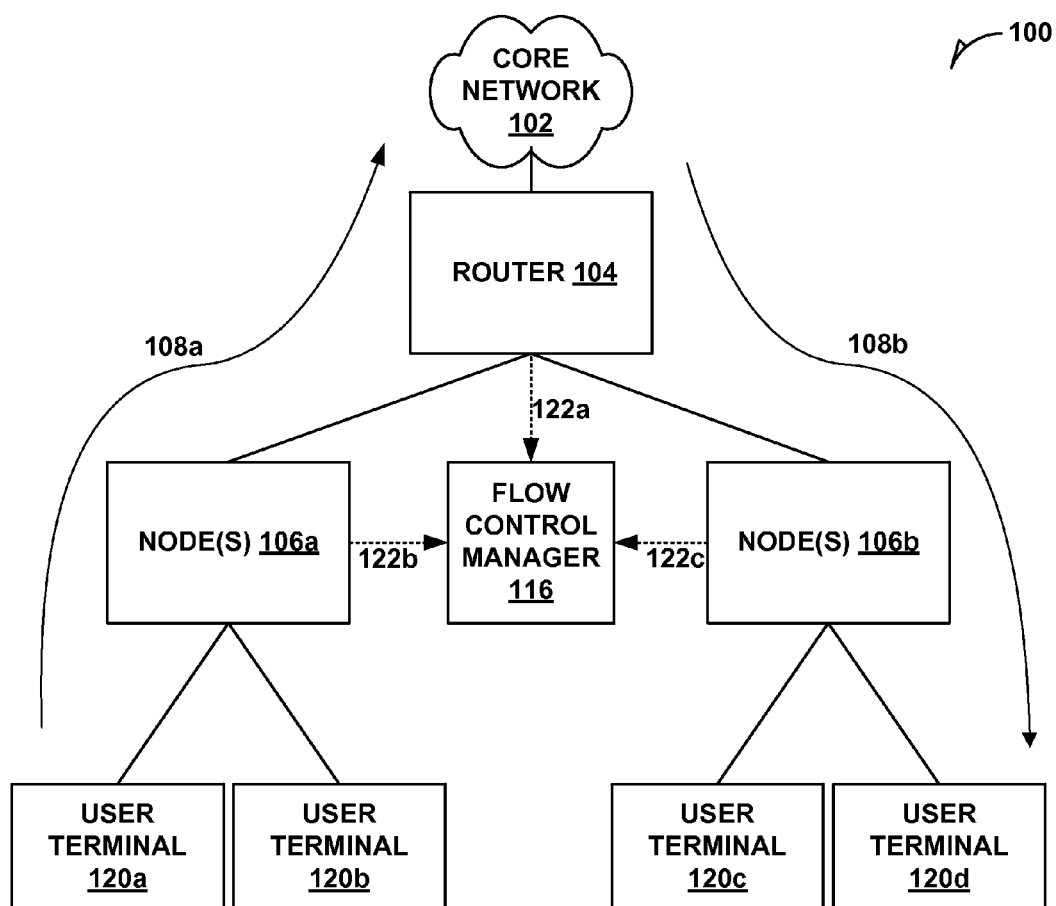
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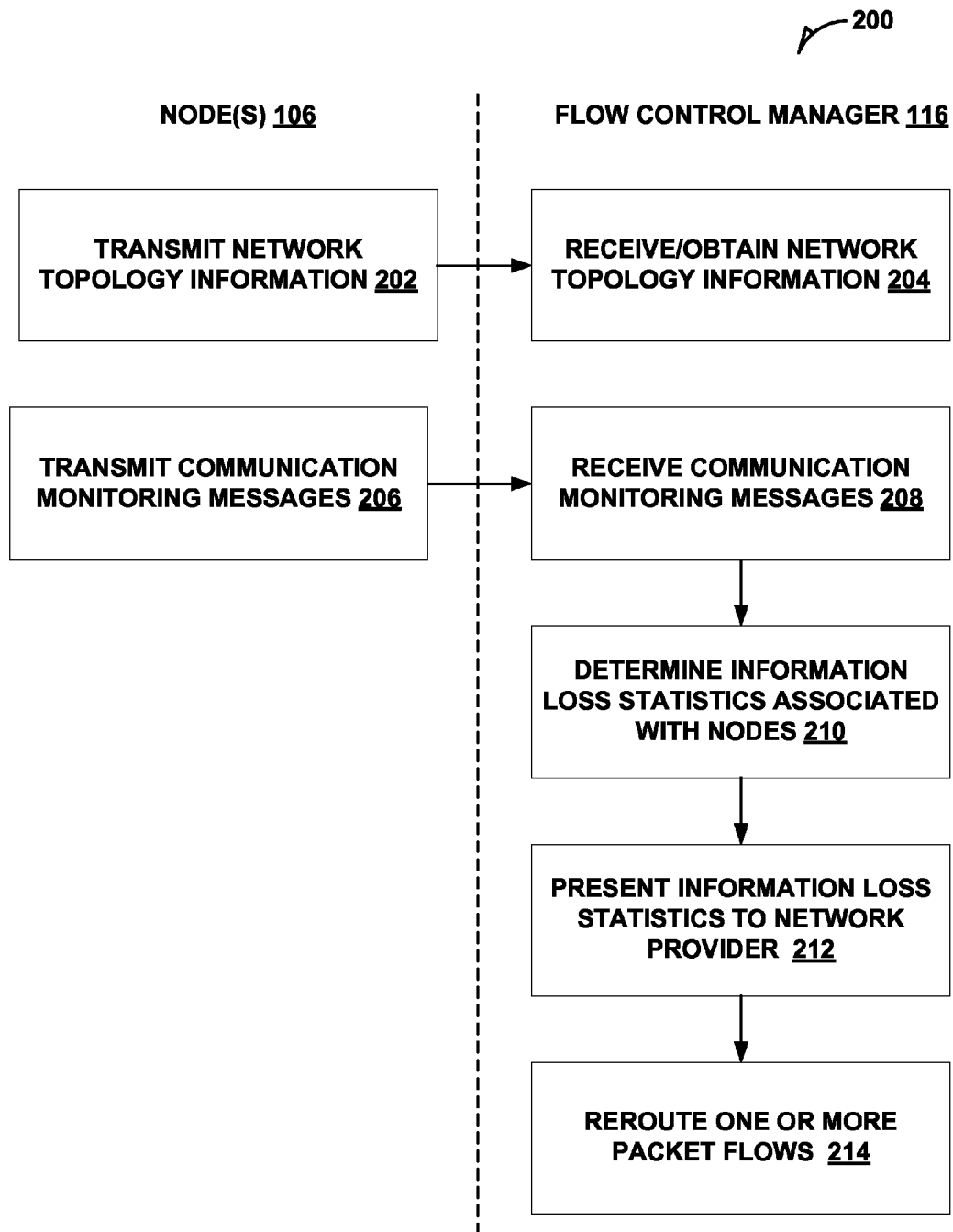
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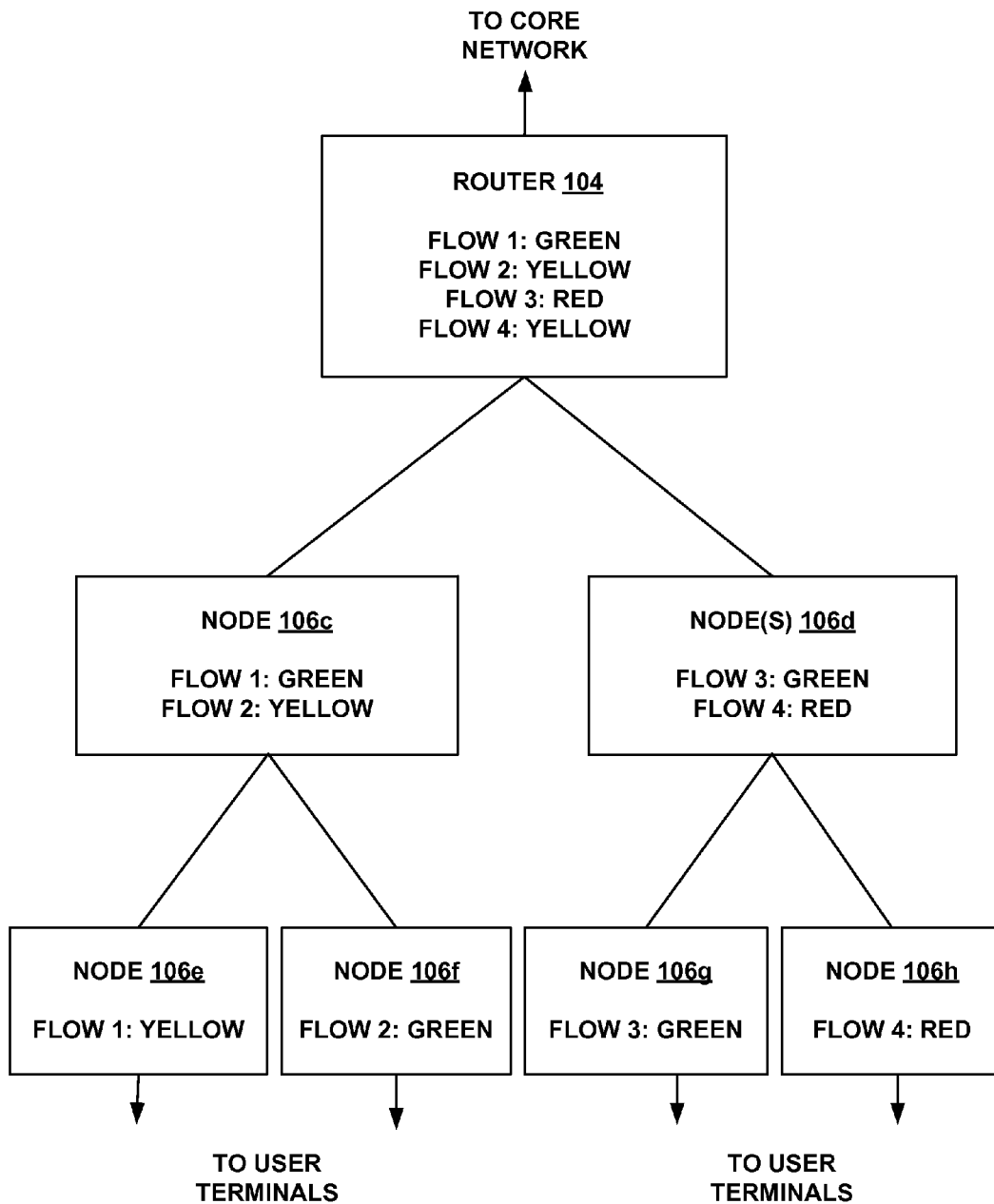
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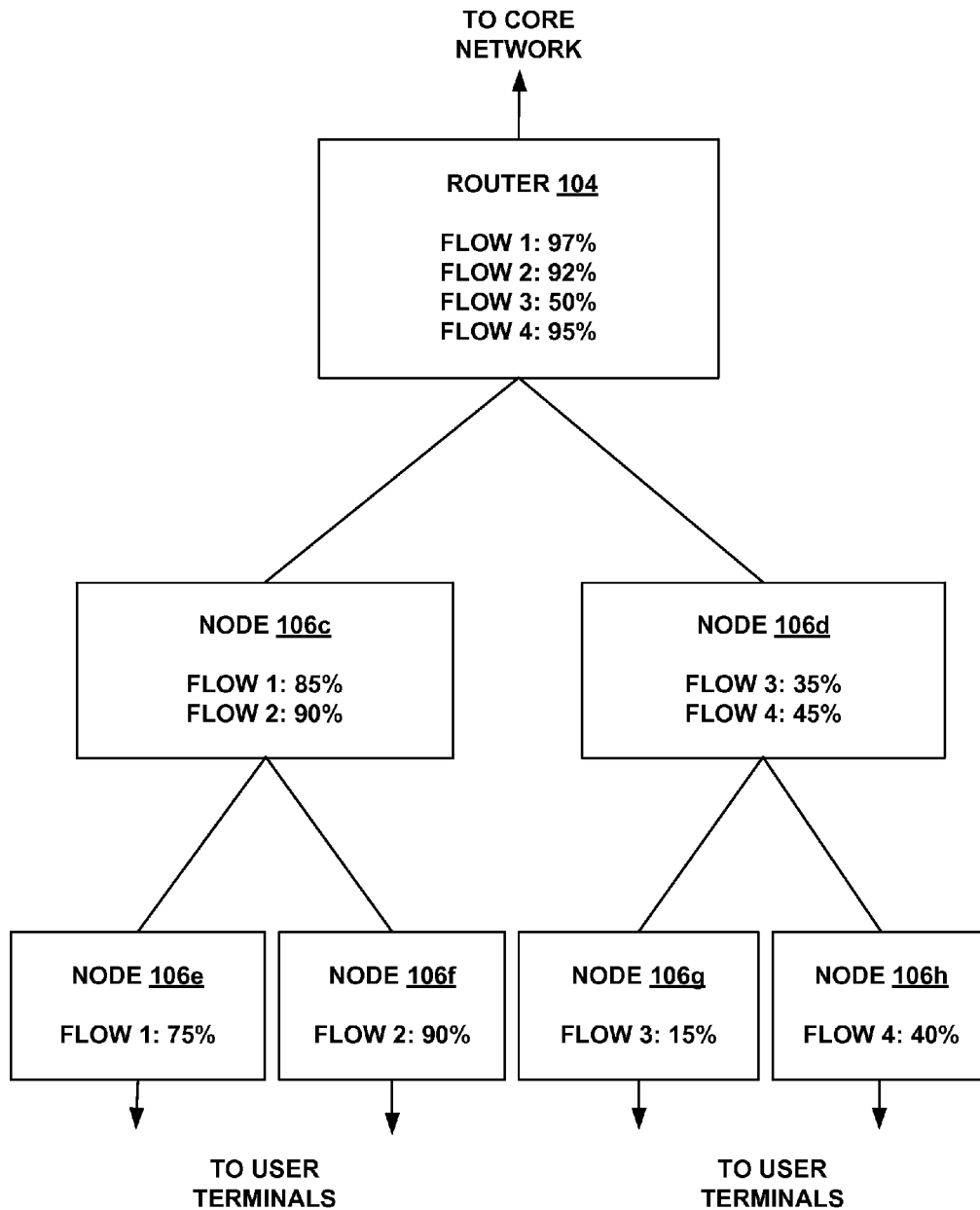
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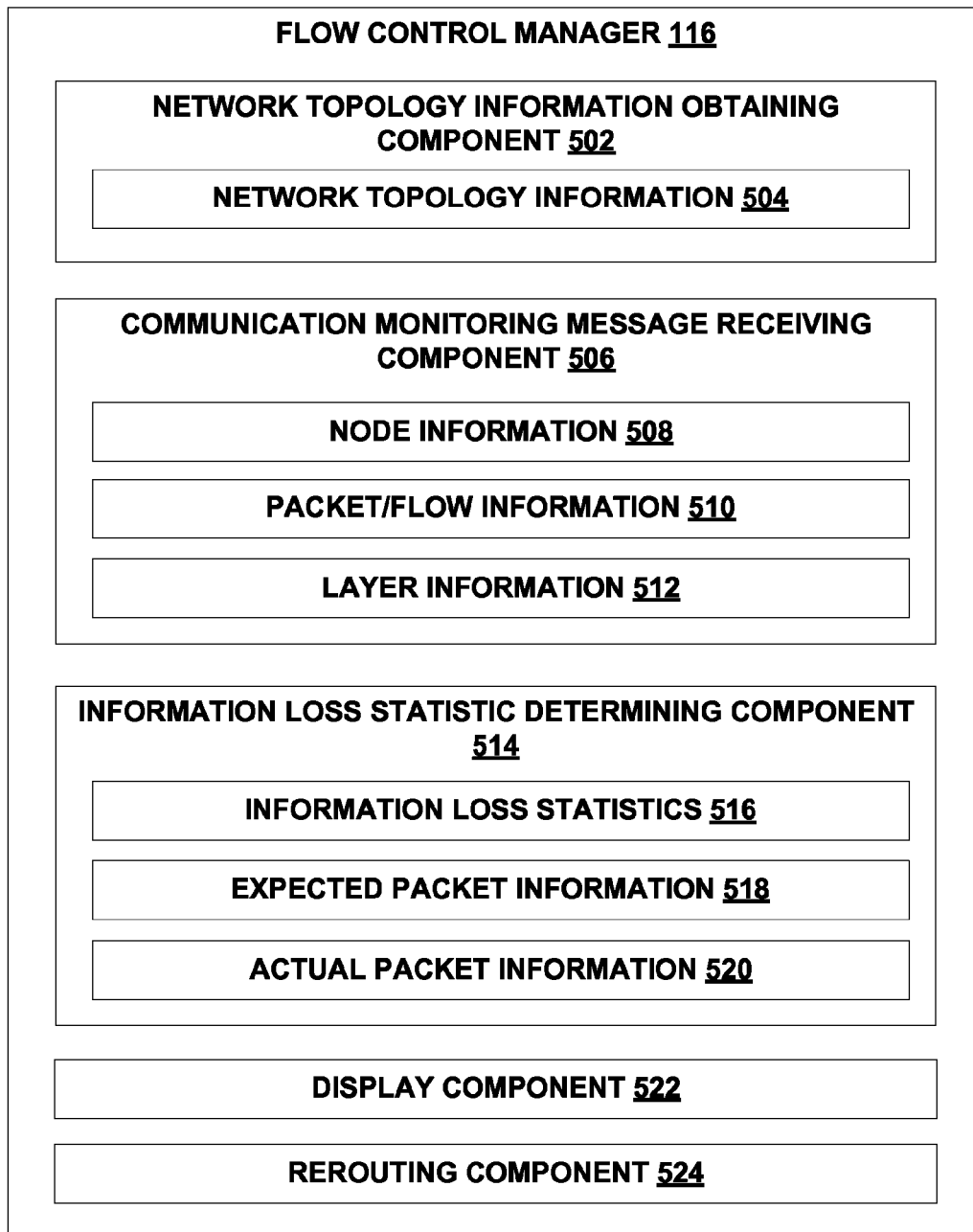
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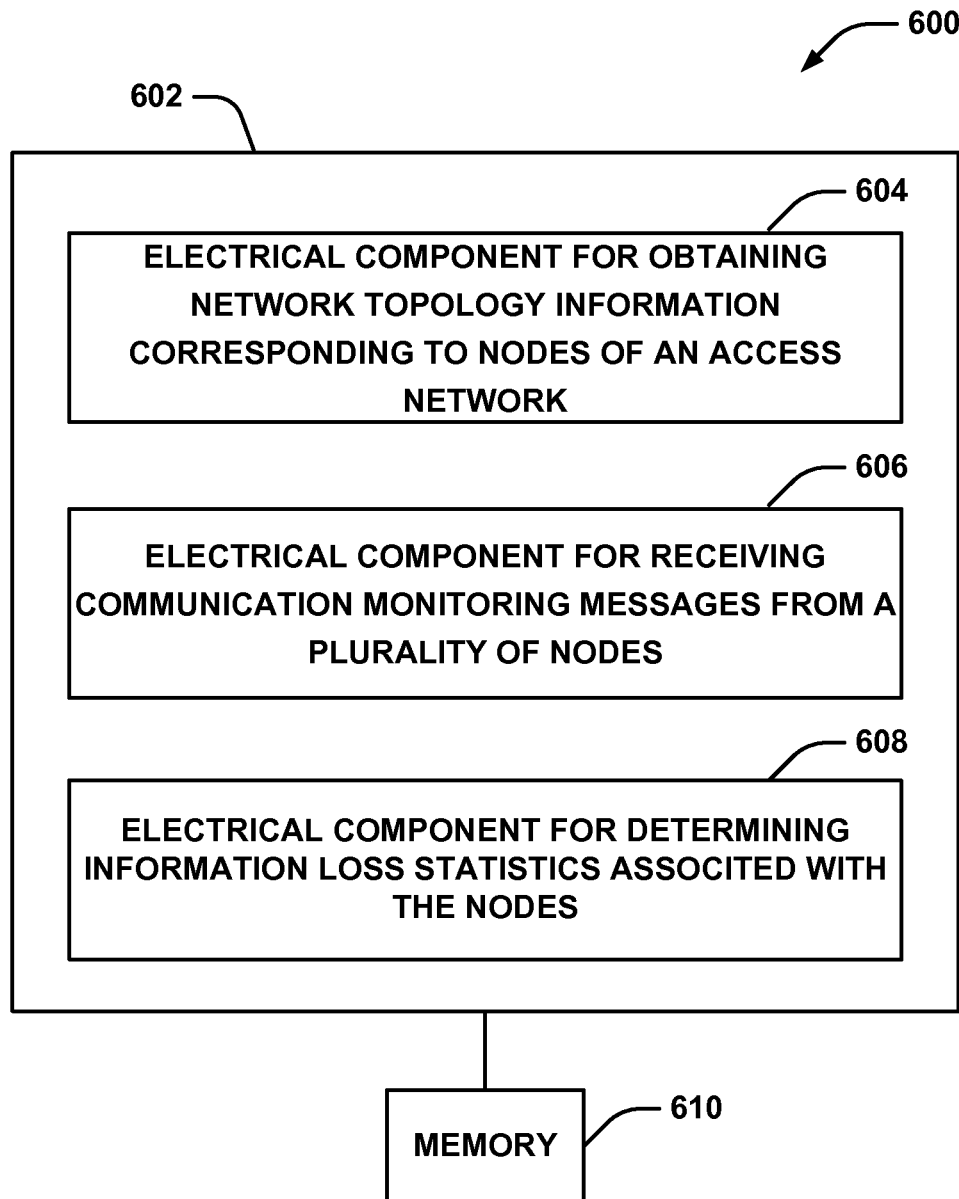
**FIG. 1**

**FIG. 2**

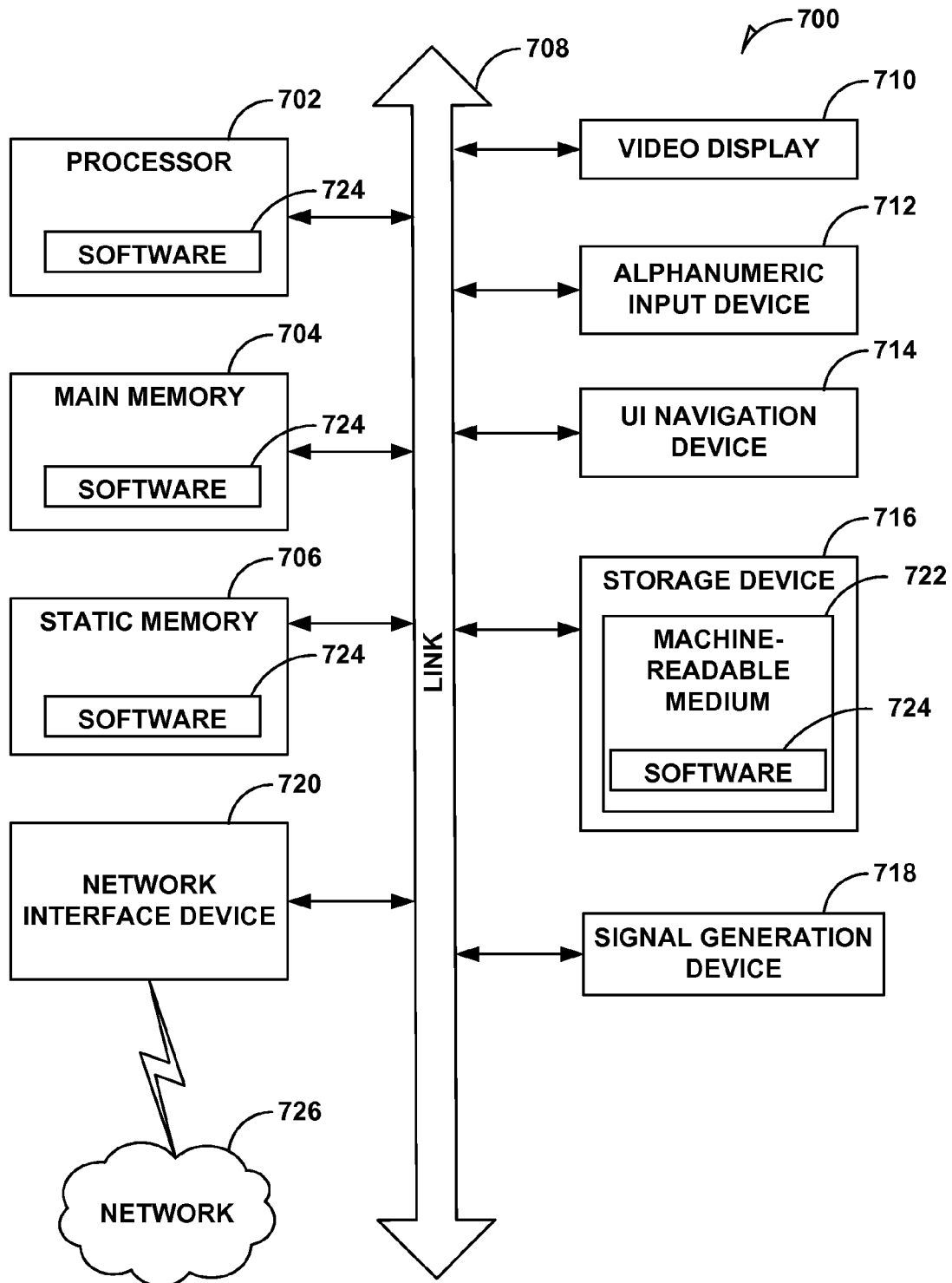
**FIG. 3**

**FIG. 4**

**FIG. 5**

**FIG. 6**



**FIG. 7**

1

# METHODS AND APPARATUSES FOR NETWORK FLOW ANALYSIS AND CONTROL

## TECHNICAL FIELD

This disclosure relates generally to network communications and in particular to methods and apparatuses for network flow analysis and control.

## BACKGROUND

Network providers currently face the challenge of maintaining the integrity of numerous communication flows across an access network, even where the network conditions are less than ideal. To meet this challenge, the network providers must determine locations of the nodes (e.g. switches, network elements, etc.) in the network that are causing the access network to behave in a sub-optimal fashion and remedy the situation, for example, by rerouting or dropping packets.

Locating the problem nodes often involves obtaining and analyzing network traffic information associated with the nodes of a network. Currently, however, this information is often obtained from a single network device, such as a router, that is located at the interface of a core network (e.g. the Internet) and the access network, and typically involves flow information associated with a single communication layer of the Open Systems Interconnection (OSI) model. For example, in some legacy access networks, a router obtains and analyzes Internet Protocol information (Layer 3 information) before reporting the status of packet flows to the network provider. Such methods for flow analysis, however, are limited in the amount of information relied upon for the traffic reports and overall flow management. Thus, methods and apparatuses for improved network flow analysis are needed.

## SUMMARY

The present disclosure presents methods and apparatuses for network packet flow analysis and control. In one example, this disclosure is directed to a method of packet flow control, which includes obtaining network topology information corresponding to a plurality of nodes of a network, receiving communication monitoring messages from two or more of the plurality of nodes, wherein the communication monitoring messages include communication information corresponding to a plurality of communication layers, and determining information loss statistics associated with the plurality of nodes based on the communication monitoring messages and the network topology information.

Furthermore, the present disclosure presents an example apparatus for packet flow analysis and control in a network, which includes one or more components for performing the acts of: obtaining network topology information corresponding to a plurality of nodes of a network, receiving communication monitoring messages from at least two of the plurality of nodes, wherein the communication monitoring messages include communication information corresponding to a plurality of communication layers, and determining information loss statistics associated with the plurality of nodes based on the communication monitoring messages and the network topology information.

In addition, the present disclosure presents at least one machine readable medium comprising a plurality of instructions that in response to being executed on a computing device, cause the computing device to perform the acts of:

2

obtaining network topology information corresponding to a plurality of nodes of a network, receiving communication monitoring messages from at least two of the plurality of nodes, wherein the communication monitoring messages include communication information corresponding to a plurality of communication layers, and determining information loss statistics associated with the plurality of nodes based on the communication monitoring messages and the network topology information.

These and other aspects of the invention will become more fully understood upon a review of the detailed description, which follows.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating an example access network for improved flow control as described in the present disclosure.

FIG. 2 is a flow diagram illustrating an example method and message flow for improved network flow control, according to various techniques of the present disclosure.

FIG. 3 is a block diagram illustrating an example flow control manager according to the present disclosure.

FIG. 4 is an illustration of a method of displaying information loss statistics by color.

FIG. 5 is an illustration of a method of displaying information loss statistics by percentage.

FIG. 6 is a block diagram illustrating a logical grouping of electrical components according to aspects of the present disclosure.

FIG. 7 is a block diagram illustrating an example machine in the example form of a computer system, within which a set or sequence of instructions for causing the machine to perform any one of the methodologies discussed herein may be executed, according to various techniques of the present disclosure.

## DETAILED DESCRIPTION

The present disclosure presents methods and apparatuses for improved flow control in access networks based on multi-layer packet flow information received from disparate network nodes, e.g., switches, access points, network processing clusters, residential gateways, optical line terminals, optical network units, or other network elements. This packet flow information may be received via communication monitoring messages from each of the network nodes and processed to convey the relative health of the network or a network flow to a user or network provider or network device capable of rerouting flow packets. For example, the multi-layer packet flow information may comprise information related to a plurality of communication layers of the Open Systems Interconnection (OSI) model. In some examples, for instance, one or more nodes may transmit packet flow information associated with layer 1 ("L1"), layer 2 ("L2"), layer 3 ("L3"), or layer 7 ("L7") to a flow control manager, which may combine and process the multi-layer packet flow information to indicate where in the network, e.g., which node, and at which layer traffic is dropped or discarded. As a result, packets may be rerouted around problematic nodes or discarded to allow higher priority packets to be passed through. Alternatively or additionally, the packet flow information may be displayed to a user or network provider on a flow-by-flow or application-by-application basis at each node (or interface), for example, in a color-coded system where, in some examples, green represents a healthy packet flow, yellow represents an intermediate packet flow health, and red represents a poor packet

flow health where one or more packets are being dropped or the packet flow is being otherwise altered.

In some examples, the methods and apparatuses described herein will use network topology information (e.g. the inter-connection and arrangement of nodes in the network) in combination with the multi-layer packet flow information to determine the health and general direction of flow for an application or service. Specifically, the flow control manager receives communication monitoring messages from a plurality of nodes in the network per interface and determines the packet loss in and out of the respective interfaces.

This information can be expressed in several ways—for example, as a percentage of dropped packets with a particular priority; as a percentage of packets dropped while traversing a node or interface; and/or displayed next to nodes or other points in the network as a relative indicator of how many packets are dropped for the packet flow. Using this wealth of information about the packet flows traversing the access network, the flow control manager (or user or network provider) may reroute packets, drop packets of a particular packet flow, or otherwise alter network behavior to improve network conditions based on the information.

FIG. 1 illustrates an example access network **100** for improved packet flow control according to the present disclosure. In an aspect, access network **100** may provide communication services (e.g. Internet or telephonic services) to one or more user terminals **120** (including user terminals **120a**, **120b**, **120c**, and **120d**, collectively user terminals **120**) serviced by the access network **100** via one or more nodes **106** (here, including nodes **106a** and **106b**). The communication services provided by the access network **100** may include one or more upstream packet flows **108a** and/or one or more downstream packet flows **108b** (collectively, packet flows **108**) carrying one or more packets between a user terminal **120** and a core network **102**. In some examples, these one or more packet flows **108** may carry data associated with one or more applications running on a user terminal **120** and/or may include control data associated with the packet flows **108**. Furthermore, packet flows **108** may have corresponding communication layer information associated with one or more OSI model communication layers. For example, packet flow **108** may have associated layer information for layer 1 to layer 7, including physical layer information (L1), data link layer information (L2), network layer information (L3), transport layer information (L4), session layer information (L5), presentation layer information (L6), and/or application layer information (L7). In an aspect, the one or more nodes **106** and/or router **104** may periodically transmit one or more communication monitoring messages **122** (including communication monitoring messages **122a**, **122b**, and **122c**) to flow control manager **116**.

These communication monitoring messages may include layer-specific packet flow information corresponding to packets of one or more packet flows traversing the node(s) **106** and/or router **104**. For example, L1 packet flow information included in the communication monitoring messages **122** may include link information, one or more event alarms, and/or one or more port statistics associated with a node **106** or a particular network interface. Furthermore, this link information may include one or more of an alarm, burstable bandwidth information, a Peak Information Rate (PIR), a Committed Information Rate (CIR), Committed Data Rate (CDR), or an Excess Information Rate (EIR).

In some examples, L2 packet flow information included in the communication monitoring messages **122** may include Remote Network Monitoring (RMON) statistics associated with a node **106**. Furthermore, the L2 packet information may

include Switched Network Monitoring (SMON) statistics. Additionally, L3 and/or L7 information may include information associated with one or more traffic analyzer reports (e.g. Netflow reports) corresponding to Internet Protocol (IP) or application traffic of one or more packet flows. By receiving layer-specific packet flow information, each node **106** can inform the packet flow manager **116** of the layer- and application-specific status or health of packet flows at the physical level, interface level, service level, and application level to provide a network-wide snapshot of individual interface packet flow health. In an additional aspect, this multi-layer flow health visibility makes it possible for a network provider or network device to provide directives to the system to prioritize certain flows or L7 traffic. In some examples, this prioritization functionality may be categorized by Network-Based Application Recognition (NBAR) applications.

Additionally, access network **100** may comprise an Ethernet network, an optical network, such as a passive optical network (PON) or an active optical network (AON), Gigabit-capable PON (GPON), or any other communication access network, optical or otherwise, known by one of ordinary skill in the art. Furthermore, access network **100** may provide communication services to the one or more user terminals **120** via one of a bevy of network topologies, including, but not limited to tree, ring, star, mesh, bus, fiber to the curb (FTTC), fiber to the neighborhood (FTTN), fiber to the premises (FTTP), fiber to the home (FTTH), fiber to the X (FTTX) or any other network topology, architecture, or sub-architecture known to one of ordinary skill in the art.

Additionally, access network **100** and/or core network **102** may include any network type, such as, but not limited to, wide-area networks (WAN), wireless networks (e.g. 802.11 or cellular network), the Public Switched Telephone Network (PSTN) network, ad hoc networks, personal area networks (e.g. Bluetooth®) or other combinations or permutations of network protocols and network types. Such network(s) may include a single local area network (LAN) or wide-area network (WAN), or combinations of LANs or WANs, such as the Internet. In addition, access network **100** may comprise a virtual large area network (VLAN).

As those skilled in the art will readily appreciate, various aspects described throughout this disclosure may be extended to other telecommunication systems, network architectures, and communication standards. By way of example, various aspects may be extended to other Universal Mobile Telecommunications System (UMTS) systems such as Time Division Synchronous Code Division Multiple Access (TD-SCDMA), High Speed Downlink Packet Access (HSDPA), High Speed Uplink Packet Access (HSUPA), High Speed Packet Access Plus (HSPA+) and Time-Division CDMA (TD-CDMA). Various aspects may also be extended to systems employing Long Term Evolution (LTE) (in FDD, TDD, or both modes), LTE-Advanced (LTE-A) (in FDD, TDD, or both modes), CDMA2000, Evolution-Data Optimized (EV-DO), Ultra Mobile Broadband (UMB), Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX®), IEEE 802.20, Ultra-Wideband (UWB), Bluetooth, and/or other suitable systems. The actual telecommunication standard, network architecture, and/or communication standard employed will depend on the specific application and the overall design constraints imposed on the system. The various devices coupled to the access network **100** and/or core network **102** (e.g. user terminals **120**) may be coupled to the networks via one or more wired or wireless connections, as may any network devices of access network **100**.

5

Moreover, the one or more user terminals **120** may each include a personal computer, such as a desktop computer, laptop computer, tablet, or other computing device, which may include a processing device or one or more processing modules for executing one or more instructions stored on a computer-readable medium. Additionally or alternatively, the one or more user terminals may include one or more set-top boxes or set-top units that may be configured to process communication signals or packets associated with one or more packet streams. Furthermore, the one or more user terminals **120** may include one or more mobile devices, which may be known to those skilled in the art as a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a terminal, a user agent, a mobile client, a client, or some other suitable terminology.

Furthermore, one or more of nodes **106** of FIG. **1** may include one or more of any type of network device, such as an optical network unit (ONU), splitter, access point, a macro cell, including a base station (BS), node B, eNodeB (eNB), a relay, a peer-to-peer device, an authentication, authorization and accounting (AAA) server, a mobile switching center (MSC), a radio network controller (RNC), or a low-power access point, such as a picocell, femtocell, microcell, a switching device, routing device, or any other network device of an access network known to one of ordinary skill in the art. Additionally, for purposes of the present disclosure, the term “upstream” may designate a direction of communication or network architecture originating at a point closer to user terminals **120** and moving toward core network **102**. Likewise, for purposes of the present disclosure, the term “downstream” may designate a direction of communication or network architecture originating at a point closer to core network **102** moving toward user terminals **120**. These flow directions are indicated by the up and downstream directional pointers of packet flow **108**, which may comprise one or both of upstream or downstream packet flows. Furthermore, as indicated in FIG. **1**, each upstream network device may communicate with a plurality of downstream network devices, for example, such that a tree network architecture is achieved, though any form of network topology (e.g. ring, mesh, etc.) is within the scope of the present disclosure. In other words, router **104** may communicate with a plurality of downstream nodes **106**, each of the plurality of nodes **106** may communicate with a plurality of downstream user terminals **120** or further nodes **106**.

Furthermore, in some examples, flow control manager **116** may be configured to receive network topology information and a plurality of communication monitoring messages to one or more packet flows associated with one or more user terminals **120** or applications running thereon. Upon receiving this information, the flow control manager **116** may analyze the information to determine the relative health of packet flows traversing the network and may display the relative health of the packet flows to a user or network provider.

In one non-limiting example, a downstream packet flow **108b** carrying information from the core network **102** to a user terminal **120** may travel through node **106b**. In an aspect, the downstream packet flow **124** may carry downstream data related to a video streaming service. The flow control manager **116** may obtain an indication of network congestion at a node **106b** along the downstream path of the video streaming downstream packet flow **108b**. In some instances, this may disrupt the integrity of the video streaming user experience at

6

user terminal **120**. Therefore, in an attempt to remedy the network congestion condition, the flow control manager **116**, router **104**, or other device or component may reroute downstream packet flow **108b** to a different packet flow route, increase bandwidth associated with downstream packet flow **108b**, or drop lower priority traffic as to avoid the one or more problem nodes of nodes **106b** causing the congestion or at which congestion exists.

FIG. **2** is a flowchart illustrating an example method **200** for improved packet flow management in access networks according to examples of the present disclosure. FIG. **2** provides the example methodology as performed by a packet flow manager (e.g. packet flow manager **116** of FIG. **1**) and one or more nodes (e.g. nodes **106** of FIG. **1**) in an access network.

In an aspect of methodology **200**, node **106** may transmit network topology information to flow control manager **116** at block **202**. This network topology information may include information regarding the orientation of the node **106** in relation to other nodes **106**, user terminals **120**, or one or more other network devices. For example, the network topology information may identify the other network devices or user terminals to which node **106** is communicatively coupled, the hardware profile, bandwidth information, service information, or other characteristics of the node **106**. In addition, at block **204**, flow control manager **116** may receive or otherwise obtain the network topology information **204**.

In addition, at block **206**, the one or more nodes may transmit one or more communication monitoring messages **206** to flow control manager **116**. The communication monitoring messages may include layer-, flow-, and/or application-specific packet flow information, such as, but not limited to, a number of packets sent or received, number or percentage of packets dropped, queued, retransmitted, hypertext transfer protocol (HTTP) uniform resource locator (URL) information, or any other communication-related statistics or information.

For example, the communication monitoring information may include associated layer information for layers 1 to layer 7, including physical layer information (L1), data link layer information (L2), network layer information (L3), transport layer information (L4), session layer information (L5), presentation layer information (L6), and/or application layer information (L7). As stated above, these communication monitoring messages may include layer-specific packet flow information corresponding to packets of one or more packet flows traversing the node(s) **106** and/or router **104** of FIG. **1**. For example, L1 packet flow information included in the communication monitoring messages may include link information, one or more event alarms, and/or one or more port statistics associated with a node **106** or a particular network interface.

In some examples, L2 packet flow information included in the communication monitoring messages **122** may include Remote Network Monitoring (RMON) statistics associated with a node **106**. Furthermore, the L2 packet flow information may include Switched Network Monitoring (SMON) statistics. Additionally, L3 and/or L7 information may include information associated with one or more traffic analyzer reports (e.g. Netflow reports) corresponding to Internet Protocol (IP) or application traffic of one or more packet flows, Deep Packet Inspection information, logs, or external applications (e.g. content delivery network or video platform information). Moreover, the communication monitoring messages **206** may include expected packet information, such as the number of packets or data units expected to traverse the node (which may be determined at one or more network ingress

points, such as a router), and actual packet information, such as the actual amount of packets or data units received or transmitted at the node **106**.

Furthermore, at block **208**, the flow control manager **116** may receive the one or more communication monitoring messages from one or more nodes **106**. In some examples, communication monitoring messages may be received from a plurality of nodes, which may include communication information corresponding to a plurality of communication layers. For example, flow control manager **116** may receive a first communication monitoring message from a first network switch that includes SMON statistical information (L2 information) associated with a first and second flow. In addition, flow control manager **116** may receive a second communication monitoring message from a second network switch that includes traffic analyzer (Netflow, Deep-Packet Inspection, L3 and/or L7) information associated with the first and second flow.

Based on the received communication monitoring messages, the flow control manager **116** may determine information loss statistics associated with one or more nodes corresponding to one or more packet flows at block **210**. For example, to determine the information loss statistics, flow control manager **116** may analyze the information associated with a particular node, communication layer, interface, application, or packet flow received via a plurality of communication monitoring messages and may determine a number or percentage of packets of a packet flow that have been altered (e.g. dropped, suspended, queued, retransmitted, or otherwise delayed) at the particular node, communication layer, interface, or the like. In some examples, this may include comparing actual packets received or transmitted to expected packets (received or transmitted) at a layer, interface, or node to determine whether packets have been dropped or otherwise altered.

Furthermore, at block **212**, the flow control manager **116** may present the information loss statistics associated with the nodes to a user or network provider. For example, the flow control manager **116** may include executable instructions stored on a computer-readable medium (e.g. a storage component) for displaying the information loss statistics and may be communicatively coupled to a display device. This display device may present the information loss statistics to the user of network provider on a per-layer, per-interface, per-device, and/or per-flow (e.g. service flow or application flow) basis. For example, the flow control manager **116** may be configured to display the information loss statistics as a color associated with each flow of the network. Green may indicate good flow health, yellow may indicate average flow health, and red may indicate poor flow health. For purposes of the present invention, the term “health” in reference to a network or packet flow may refer to a certain percentage of packets of the packet flow or network being altered (e.g. dropped, queued, retransmitted, or otherwise interrupted). This percentage may differ according to application type. In a non-limiting example, a “green” indication may indicate that less than five percent of packets are altered, a “yellow” indication may indicate that 5 percent to less than 25 percent of packets are altered, and a “red” indication may indicate that 25 percent or more of packets are altered. Alternatively or additionally, the flow control manager **116** may present the information loss statistics as a percentage of packets altered (or not altered) at a particular interface, node, or other network device.

Furthermore, at block **214**, the flow control manager **116** may be configured to reroute one or more packet flows based on the information loss statistics. In an aspect, this rerouting

may be executed by one or more other network devices, such as a router, switch, or other node based on a command transmitted by the flow control manager **116**. In other examples, the flow control manager **116** may play no part in the rerouting; rather, the rerouting may be executed by the router, switch, or other node based on direct control signal communication between a network provider or user device and the router, switch, or other node based on the presented information loss statistics.

In this manner and in contrast to existing techniques, two or more nodes may transmit network topology information and communication monitoring messages associated with a plurality of communication layers to a flow control manager, which may be utilized to perform packet flow control at disparate network locations. As such, packet flow control may be optimized by analyzing myriad packet flow statistics corresponding to multiple disparate network devices, flows, or interfaces throughout an access network.

FIG. **3** is a diagram illustrating an example program interface displaying network health statistics to a user or network provider according to the present disclosure. FIG. **3** presents a representation of an access network (e.g. access network **100** of FIG. **1**), including a router **104** and nodes **106c**, **106d**, **106e**, **106f**, **106g**, and **106h** (collectively, nodes **106**) of the access network. Each of the router and nodes include at least one associated packet flows (“flows”), which include flows 1 to 4, each of which may correspond to an application or program executed by a user terminal and requiring communication with a core network through the access network.

As shown in FIG. **3**, each of the flows may be identified and color coded to indicate the health of each flow at each node **106** and/or router. For example, moving downstream from the core network to the user terminals, flow 1 moves from a relatively healthy communication flow at the router **104** and the next-level node **106c** (indicated by a “green” indication) to a relatively intermediate or average health at the lower node **106e**. This may indicate that the health of flow 1 is degraded as it moves downstream. Based on this display of information loss statistics, the user or network provider may attempt to reroute one or more of the flows in an attempt to avoid a node that indicates relatively poor flow health for one or more of the flows.

FIG. **4** illustrates an alternative information loss statistic display method based on displayed percentages of packets unaltered (or altered) at each of nodes **106c**, **106d**, **106e**, **106f**, **106g**, and **106h** (collectively, nodes **106**) and/or router **104**, or across the access network in total. FIG. **4** illustrates the downstream health of packet flows 1 to 4 by displaying the percentage of packets that successfully traverse router **104** and nodes **106**. As such, a user or network provider may identify the network location where packet flows are degraded.

For example, moving downstream from the core network to the user terminals, flow 4 moves from a relatively healthy communication flow at the router (95% of packets successfully traversing the router) to a poor health at the intermediate node **106d** and lower node **106h** (45% and 40%, respectively). This may indicate that the health of flow 4 is degraded as it moves downstream, especially at intermediate node **106d**, where the percentage of successfully traversing packets drops to 45% of the expected packets. Based on this display of information loss statistics, the user or network provider may attempt to reroute one or more of the flows in an attempt to avoid a node (e.g. the problem intermediate node) that indicates relatively poor flow health for one or more of the flows.

FIG. **5** is a block diagram illustrating an example flow control manager **116** of access network **100** of FIG. **1**. In an aspect, flow control manager **116** may include one or more

sub-components that are configured to perform one or more acts associated with methodologies described herein (e.g. methodology **200** of FIG. 2). In some examples, flow control manager **116** may include a network topology information obtaining component **502**, which may be configured to obtain network topology information **504**, for example, from one or more nodes of an access network. In an aspect, the network topology information **504** may include information concerning the topology, arrangement, interconnection mapping, or the like, of the access network.

In addition, flow control manager **116** may include a communication monitoring message receiving component **506**, which may be configured to receive communication monitoring messages from one or more network devices (e.g. routers, nodes, switches, etc.). In some examples, the communication monitoring messages may include node information **508** corresponding to the node from which each of the communication monitoring messages originated, packet and/or flow information **510** corresponding to packet flows traversing the particular nodes (e.g. packet, application, and/or user terminal identifying information), and layer information **512** identifying the communication layer to which the communication monitoring message pertains. In addition, communication monitoring messages may include prioritization information that may indicate that certain types of traffic or L7 flows should be prioritized over others.

Furthermore, flow control manager **116** may include an information loss statistic determining component **514**, which may be configured to determine information loss statistics **516** associated with one or more nodes, routers, interfaces, or other network devices of an access network. In an aspect, information loss statistic determining component **514** may determine the loss statistics based on the communication monitoring messages received by communication monitoring message receiving component **506**. In some examples, information loss statistic determining component **514** may determine the information loss statistics **516** based on comparing expected packet information **518** to actual packet information **520**, for example, to determine a percentage of packets that have been altered by one or more nodes, routers, switches, or other network devices.

In addition, flow control manager **116** may include a display component, which may be configured to display the information loss statistics **516** to a user or network provider. Furthermore, flow control manager **116** may include a rerouting component **524**, which may be configured to reroute one or more packets of one or more packet flows associated with the access network.

Referring to FIG. 6, a block diagram illustrating an example system **600** is displayed for improved packet flow control on an access network. For example, system **600** can reside at least partially within one or more computing or processing devices, which may include, in a non-limiting aspect, any network device described herein, including, but not limited to, flow control manager **116** of FIG. 1.

It is to be appreciated that system **600** is represented as including functional blocks, which can be functional blocks that represent processes implemented by a processor, software, or combination thereof (e.g., firmware). System **600** includes a logical grouping **602** of electrical components that can act in conjunction. For instance, logical grouping **602** can include an electrical component **604** for obtaining network topology information corresponding to node of an access network. In an aspect, electrical component **604** may comprise network topology information obtaining component **502** (FIG. 5). In addition, logical grouping **602** can include an electrical component **606** for receiving communication moni-

toring messages from a plurality of nodes. In an aspect, electrical component **606** may comprise communication monitoring message receiving component **506** (FIG. 5). In addition, logical grouping **602** can include an electrical component **608** for determining information loss statistics associated with the nodes. In an aspect, electrical component **608** may comprise information loss statistic determining component **514** (FIG. 5).

Additionally, system **600** can include a memory **610** that retains instructions for executing processes associated with the electrical components **604**, **606**, and **608**, stores data used or obtained by the electrical components **604**, **606**, and **608**, etc. While shown as being external to memory **610**, it is to be understood that one or more of the electrical components **604**, **606**, and **608** can exist within memory **610**. In one example, electrical components **604**, **606**, and **608** can comprise at least one processor, or each electrical component **604**, **606**, and **608** can be a corresponding module of at least one processor. Moreover, in an additional or alternative example, electrical components **604**, **606**, and **608** can be a computer program product including a computer readable medium, where each electrical component **604**, **606**, and **608** can be corresponding code.

FIG. 7 is a block diagram illustrating a machine in the example form of a computer system **700**, which may represent one or more of the devices introduced above, including, but not limited to, flow control manager **116**, or any of the access network devices of FIG. 1. Within the example computer system **700** are a set or sequence of instructions for causing the machine to perform any one of the methodologies discussed herein may be executed, according to an example embodiment. In alternative embodiments, the machine operates as a standalone device or may be connected (e.g. networked) to other machines. In a networked deployment, the machine may operate in the capacity of either a server or a client machine in server-client network environments, or it may act as a peer machine in peer-to-peer (or distributed) network environments. The machine may be a personal computer (PC), a tablet PC, a set-top box (STB), a Personal Digital Assistant (PDA), a mobile telephone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

Example computer system **700** includes at least one processor **702** (e.g. a central processing unit (CPU), a graphics processing unit (GPU) or both, processor cores, computer nodes, etc.), a main memory **704** and a static memory **706**, which communicate with each other via a link **708** (e.g. bus). The computer system **700** may further include a video display unit **710**, an alphanumeric input device **712** (e.g. a keyboard), and a user interface (UI) navigation device **714** (e.g. a mouse). In one embodiment, the video display unit **710**, input device **712** and UI navigation device **714** are incorporated into a touch screen display. The computer system **700** may additionally include a storage device **716** (e.g. a drive unit), a signal generation device **718** (e.g. a speaker), a network interface device **720**, and one or more sensors (not shown), such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor.

The storage device **716** includes a machine-readable medium **722** on which is stored one or more sets of data structures and instructions **724** (e.g. software) embodying or

11

utilized by any one or more of the methodologies or functions described herein. The instructions 724 may also reside, completely or at least partially, within the main memory 704, static memory 706, and/or within the processor 702 during execution thereof by the computer system 700, with the main memory 704, static memory 706, and the processor 702 also constituting machine-readable media.

While the machine-readable medium 722 is illustrated in an example embodiment to be a single medium, the term “machine-readable medium” may include a single medium or multiple media (e.g. a centralized or distributed database, and/or associated caches and servers) that store the one or more instructions 724. The term “machine-readable medium” shall also be taken to include any tangible medium that is capable of storing, encoding or carrying instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure or that is capable of storing, encoding or carrying data structures utilized by or corresponding to such instructions. The term “machine-readable medium” shall accordingly be taken to include, but not be limited to, solid-state memories, and optical and magnetic media. Specific examples of machine-readable media include non-volatile memory, including, by way of example, semiconductor memory devices (e.g. Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks.

The instructions 724 may further be transmitted or received over a communications network 726 using a transmission medium via the network interface device 720 utilizing any one of a number of well-known transfer protocols (e.g. HTTP). Examples of communication networks include a local area network (LAN), a wide area network (WAN), the Internet, mobile telephone networks, Plain Old Telephone (POTS) networks, and wireless data networks (e.g. Wi-Fi, 3G, and 4G LTE/LTE-A or WiMAX networks). The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding, or carrying instructions for execution by the machine, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

Examples, as described herein, may include, or may operate on, logic or a number of modules, modules, or mechanisms. Modules are tangible entities capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g. internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g. a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g. instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may reside (1) on a non-transitory machine-readable medium or (2) in a transmission signal. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

Accordingly, the terms “component,” “components,” “module” and “modules” are understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g. hardwired), or temporarily (e.g. transitorily) configured (e.g. programmed) to operate in a specified manner or to perform part or all of any operation

12

described herein. Considering examples in which modules are temporarily configured, one instantiation of a module may not exist simultaneously with another instantiation of the same or different module. For example, when the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Accordingly, software may configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

Additional examples of the presently described method, system, and device embodiments include the following, non-limiting configurations. Each of the following non-limiting examples may stand on its own, or may be combined in any permutation or combination with any one or more of the other examples provided below or throughout the present disclosure. The preceding description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments.

What is claimed is:

1. A method for network monitoring, comprising:

obtaining, from a plurality of nodes of a network, network topology information corresponding to the plurality of nodes of the network, wherein the network topology information includes the orientation of each node of the plurality of nodes in relation to each other node of the plurality of nodes;

receiving communication monitoring messages from at least two nodes of the plurality of nodes, wherein the communication monitoring messages include communication information corresponding to a plurality of communication layers;

determining information loss statistics associated with the plurality of nodes and a packet flow corresponding with the plurality of nodes based on the communication monitoring messages and the network topology information;

determining an application corresponding with the packet flow from the communication monitoring messages;

determining a priority for the identified application from the communication monitoring messages;

calculating a relative health value for the packet flow at a second node of the plurality of nodes using a percentage of packets that have been altered while traversing the second node, wherein the percentage of packets that have been altered while traversing the second node are used to determine the information loss statistics corresponding with the second node; and

configuring a first node of the plurality of nodes responsible for transmitting the packet flow to transmit the packet flow to a third node of the plurality of nodes rather than the second node of the plurality of nodes using the priority and the relative health value of the packet flow at the second node of the plurality of nodes.

2. The method of claim 1, wherein the plurality of communication layers includes layer 1 and the communication information comprises link information.

3. The method of claim 2, wherein the link information comprises one or more of an alarm, burstable bandwidth information, a Peak Information Rate (PIR), a Committed Information Rate (CIR), Committed Data Rate (CDR), or an Excess Information Rate (EIR).

## 13

4. The method of claim 1, wherein the plurality of communication layers includes layer 2 and the communication information comprises one or both of Switch Monitoring (SMON) information or Remote Network Monitoring (RMON) information.

5. The method of claim 1, wherein the plurality of communication layers includes layer 3 and the communication information comprises Internet Protocol (IP) information.

6. The method of claim 1, wherein the plurality of communication layers includes layer 7 and the communication information comprises application-specific information.

7. The method of claim 1, wherein the communication information is associated with one or more packet flows.

8. The method of claim 1, wherein the communication information comprises dropped packet information.

9. The method of claim 1, wherein determining information loss statistics comprises:

obtaining expected packet information; and  
comparing the expected packet information to actual packet information, wherein the actual packet information is included in the communication information messages.

10. The method of claim 1, further comprising displaying the information loss statistics.

11. An apparatus for managing packet flow in a network, comprising:

at least one processor;  
at least one non-transitory machine readable medium with instructions stored thereon, wherein when the instructions are executed by the at least one processor the at least one processor is configured to:

obtain, from a plurality of node of a network, network topology information corresponding to the plurality of nodes of the network, wherein the network topology information includes the orientation of each node of the plurality of nodes in relation to each other node of the plurality of nodes;

receive communication monitoring messages from two or more nodes of the plurality of nodes, wherein the communication monitoring messages include communication information corresponding to a plurality of communication layers;

determine information loss statistics associated with the plurality of nodes and a packet flow corresponding with the plurality of nodes based on the communication monitoring messages and the network topology information;

determine an application corresponding with the packet flow from the communication monitoring messages; determine a priority for the identified application from the communication monitoring messages;

calculate a relative health value for the packet flow at a second node of the plurality of nodes using a percentage of packets that have been altered while traversing the second node, wherein the percentage of packets that have been altered while traversing the second node are used to determine the information loss statistics corresponding with the second node; and

configure a first node of the plurality of nodes responsible for transmitting the packet flow to transmit the packet flow to a third node of the plurality of nodes rather than the second node of the plurality of nodes using the priority and the relative health value of the packet flow at the second node of the plurality of nodes.

12. The apparatus of claim 11, wherein the instructions to determine information loss statistics further configure the processor to:

## 14

obtain expected packet information; and  
compare the expected packet information to actual packet information, wherein the actual packet information is included in the communication information messages.

13. The apparatus of claim 11, wherein the instructions further configure the processor to display the information loss statistics.

14. The apparatus of claim 11, wherein the communication information is associated with one or more packet flows.

15. The apparatus of claim 11, wherein the communication information comprises dropped packet information.

16. At least one non-transitory machine readable medium comprising a plurality of instructions that in response to being executed on a computing device, cause the computing device to perform the acts of:

obtaining, from a plurality of nodes of a network, network topology information corresponding the plurality of nodes of the network, wherein the network topology information includes the orientation of each node of the plurality of nodes in relation to each other node of the plurality of nodes;

receiving communication monitoring messages from two or more nodes of the plurality of nodes, wherein the communication monitoring messages include communication information corresponding to a plurality of communication layers;

determining information loss statistics associated with the plurality of nodes and a packet flow corresponding with the plurality of nodes based on the communication monitoring messages and the network topology information;

determining an application corresponding with the packet flow from the communication monitoring messages; determining a priority for the identified application from the communication monitoring messages;

calculating a relative health value for the packet flow at a second node of the plurality of nodes using a percentage of packets that have been altered while traversing the second node, wherein the percentage of packets that have been altered while traversing the second node are used to determine the information loss statistics corresponding with the second node; and

configuring a first node of the plurality of nodes responsible for transmitting the packet flow to transmit the packet flow to a third node of the plurality of nodes rather than the second node of the plurality of nodes using the priority and the relative health value of the packet flow at the second node of the plurality of nodes.

17. The at least one machine readable medium of claim 16, comprising further instructions that in response to being executed on the computing device, cause the computing device to perform the acts of:

obtaining expected packet information; and  
comparing the expected packet information to actual packet information, wherein the actual packet information is included in the communication information messages.

18. The at least one machine readable medium of claim 16, comprising further instructions that in response to being executed on the computing device, cause the computing device to perform the acts of displaying the information loss statistics.

19. The at least one machine readable medium of claim 16, wherein the communication information is associated with one or more packet flows.



**15**

**20.** The at least one machine readable medium of claim **16**, wherein the communication information comprises dropped packet information.

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**16**